A Synthetic Liquid Fuels Industry Non-Technologic Factors

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I. Introduction

Commercial production of synthetic liquid fuels from tar sands, oil shale and coal has been accomplished using each of these resources. Asphalt deposits occurring at the surface, which are a specialized type of tar sand, were used as early as biblical times in the Middle East countries. Based on tar sands, a plant with a capacity of 45,000 barrels of oil per day was dedicated in September of 1967 by Great Canadian Oil Sands Ltd. near Fort McMurray, Alberta, Canada, and is now in operation. The earliest reported commercial production of liquid fuels from oil shale was in France in 1839 but there were relatively large industries in Germany and Scotland during the 1800's. Commercial production is still reported in the U.S.S.R., Spain, Sweden, and China (mainland). Liquid products from coal first were produced as a by-product of coal carbonization and represented only 5% of the original coal substance. Production of liquid products such as "coal oil" for use as a fuel for lamps was commercially practiced as early as the latter part of the 19th century. Large scale production of liquid fuels by direct hydrogenation of coal started in 1926 in Germany. This was followed in 1933 by commercial production of liquid products from the catalytic reaction of carbon monoxide and hydrogen produced by gas manufactured from coal (the Fischer Tropsch process). Production in Germany continued on a large scale until the end of World War II when the plants were either destroyed or gradually converted to other uses. Relatively small scale plants for converting coal to liquid products were operated in a number of other countries during the period 1935 to 1960 but the only commercial synthetic liquid fuel from coal plant now in operation is a Fischer Tropsch plant in South Africa.

II. U.S. Interest in Synthetic Liquid Fuels

Interest in synthetic liquid fuels in the U.S. has varied greatly since the turn of the century. During and following World Wars I and II interest in alternatives to liquid fuel from petroleum was at its highest peak because of shortages that had occurred during the wars. The German commercial production from coal during World War II which assisted that country to wage war was pointed to as evidence for the need to establish a commercial industry in the U.S.

Throughout nearly all of this century, except for the period following the East and West Texas discoveries in the early 1920's and in 1930, there have been repeated predictions that the U.S. would shortly "run out of oil". These predictions have largely been based on the samll inventory (approximately 11 to 20 years' supply) which the industry has traditionally maintained. A large inventory, however, would be difficult to justify economically and until the last several years the reserve to production ratio has remained relatively constant. However, after many years of remaining nearly constant, the reserve to consumption ratio of liquid hydrocarbons has declined sharply from 9.5 in 1965 to 7.5 in 1969. This has been in part an indirect effect of the increased imports of crude petroleum and residual fuel oil. Imports to the U.S. started shortly after World War II and in

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1/ Mineral Resources Research Advisor, Assistant Secretary of Mineral Resources Office spite of the oil import controls maintained on crude petroleum since 1959, for most of the U.S. the amount of imported liquid fuels now represents 23% of domestic liquid fuel consumption.

Projections of energy demand to the year 2000 have been made by a number of companies and organizations concerned with energy supply and demand. There is general agreement that by the year 2000 our energy requirement will about double. There is less uniformity in the projections about how much each of the energy sources (coal, oil, gas, uranium) will supply of this total. These projections, moreover, were made before the full impact of the new public policy of maintaining the quality of the environment could be factored into the projections. Low sulfur residual fuel oil has already made significant inroads into coal's electric utility markets on the east coast and it appears that residual will be used to replace higher sulfur coals in other marketing areas also. Even without this new consideration, liquid fuel demands were expected to increase by over 90% of 1969 consumption. The demand between 1970 and 1985 is expected to be greater than all the oil previously produced in the U.S.

Because of the declining reserve to consumption ratio and the projections for a very large demand in the future, industry has shown great interest in the past 3 years in synthetics produced from any source. The discovery of what appears to be a very large oil field in Alaska has apparently slowed research in synthetics as the oil companies reexamine the supply situation and their other investment needs. There remain major uncertainties with respect to the size of the Alaskan find as well as how and at what cost it can be brought to U.S. markets. However, unless the Alaskan discovery is much larger than even the most optimistic estimates that have been made, the onset of a synthetic industry would only be delayed a few years.

III. The Need for Synthetics

The highly competitive nature of the energy industries, because of the substitutability of energy sources at the point of use (for most purposes) and their convertability from one form to another, requires that the entire energy spectrum be examined if we are to evaluate the potential role of synthetics in the energy economy. However, because liquid fuels are necessary under today's technologic conditions for certain energy uses, it is most important to examine the alternative sources for crude oil.

The question, "Is there a need for synthetics?" can be answered in many ways. If a shortage of liquid fuels develops, there are a variety of possible solutions. Among the more obvious are: direct substitution of other, more abundant energy sources for liquid fuels; increased imports; permitting the price of oil to rise; development of improved technology for finding, producing and utilizing existing and potential oil fields; increased exploration activity; and the production of synthetics from oil shale, tar sands or coal.

Selecting one or a combination of these alternatives requires considerable study and analysis. It is easy, however, to set the major criteria which would have to be met from a national viewpoint. These would include a secure, diversified supply of liquid fuels at the lowest cost consistent with other national goals.

With today's technology, transportation is the only end use for which liquid fuels are indispensable. Even for transportation, it is possible to foresee changes that would permit a high degree of substitution for liquid products. For example, autos or planes using natural gas or a car using electricity could be used if there was sufficient incentive. Widespread use of electric cars or electric trains would permit the primary energy source to be any fossil or nuclear fuel.

IV. Non-Technologic Factors

The technology for converting oil shale, tar sands and coal into an acceptable substitute for crude oil and its products has been demonstrated on a commercial scale and is currently being used in countries other than the U.S. A proven technology at prices competitive with crude petroleum is a necessary but not sufficient prerequisite for the establishment of a synthetic liquid fuel industry. Many factors that influence both the price of crude petroleum and of synthetics will affect the timing and the rate at which an industry will develop.

1. Factors that affect competition from oil

Since synthetics would compete directly with crude oil, changes in any of the laws, regulations, or state and Federal practices that affect the domestic price of crude oil could have the greatest direct impact on a potential synthetics industry. The most important of the institutional factors influencing crude oil prices are the Oil Imports Program, the Federal depletion allowance, state prorationing practices, and Outer Continental Shelf and on-shore Federal leasing programs.

a. Oil Import Program

The Oil Import Program was created to promote a healthy domestic petroleum industry by limiting imports of low-cost foreign oil. The Program was designed to assure the Nation a secure petroleum supply and it has served to advance this purpose. However, the cost has been high: Domestic oil sells for between 75¢ and $1.25 per barrel above world prices or from 30 percent to 60 percent higher than would otherwise prevail. The majority of the Cabinet Task Force on Oil Import Control recommended to the President in February 1970 that in place of the oil import quotas which had been in use, a tariff system be substituted with a three-year phase out of the quota system. The basis for the recommendations was that this would permit some liberalization of the Program but still be designed so that indicated reserves of North America would be sufficient to meet 1980 production estimates. Adjustments in the tariff levels would be made to insure that this goal was met. There was some support at the Cabinet level for a continuation of quotas in some form rather than the tariff approach. The final decision with respect to oil import controls is still to be made.

Any changes in the Oil Import Program would have a major impact on the development of synthetics. Increasing significantly the amount of imports would tend to decrease crude oil prices, which in turn would require a competitive drop in the price of synthetics, and this would reduce the return on plant investment. Since synthetics plants are capital-intensive, even minor changes in the competitive price of crude could have a major impact on their economics. Any reduction of domestic crude prices would delay the development of a synthetics industry with the present state of conversion technology and the potential for reduction in costs by methods that have been proposed to improve that technology.

If a quota system were continued, development of a commercial synthetics industry would raise a question as to how the oil when it is refined would be treated in determining the overall size of the oil import quota. If the oil were treated the same as domestic production of crude oil, a refinery would generate a quota for the synthetics processed, and for a small refiner, this could be worth as much as 11¢ per barrel.1/

b. The depletion allowance

The depletion allowance for crude oil and gas is now 22 percent. Because of the high percentage of dry holes drilled in the search for oil, the allowance has been justified by industry on the basis that the resulting tax savings are needed to pay for exploration for new oil fields.

1/ The difference between the price of imported and domestic oil is about $1.25 in the East and each barrel of domestic oil used in a refinery generates .090 barrels of oil import quota. Thus $1.25 X .09 = 11¢/bbl.

The oil industry has urged repeatedly that oil from shale receive the same tax treatment as crude oil, presumably because shale oil would be in direct competition with crude oil. Until this past year, the depletion allowance was 15 percent on the value of the mined rock. At this rate, the allowance is equivalent to about 18 cents per barrel of semirefined shale oil (before taxes). The 1969 Tax Act changed the depletion allowance to 15 percent on the shale oil and this would be equivalent to about 35 cents per barrel of shale oil at the retort. Depletion allowance on coal is 10 percent on the mined coal and this is estimated to be worth about 15 cents per barrel. Table 1 shows the effect on costs of various levels of depletion allowance when taken on the mined raw material and on the liquid, refined to two levels of quality.

c. State prorationing

State prorationing practices were developed to conserve oil, i.e., to prevent producing oil above the maximum efficient rate either for the purpose of recovering an investment quickly or preventing drainage of oil from a deposit by adjacent producers in the same field. Actually, however, prorationing practices have had the effect of maintaining a stable price for crude oil. Crude oil prices remained relatively constant for a 10-year period, but started to climb in 1968 with a 3 cents per barrel price rise followed by a 12 cents per barrel rise in 1969.

If prorationing were stopped, at least in the initial stage of development of synthetics, the synthetic industry might be adversely affected because crude prices would be expected to drop. This, in turn, would eliminate the high cost marginal wells, and as a result at some later time prices might tend to rise.

As long as the synthetic industry remained relatively small, the impact on those states practicing prorationing would be small, but as the productive capacity became significant some method would have to be developed to accommodate synthetics to the crude oil.

d. Federal leasing policies

If synthetics become competitive at present domestic prices of crude oil, interest in leasing of Federal oil and gas lands could be expected to decline. Since Outer Continental Shelf leasing is generally believed to offer more favorable opportunities for discovery, it would be affected less than on-shore leases. Nevertheless, the large amounts of capital required for synthetics plants might reduce interest in the Outer Continental Shelf and reduce the amounts of the bonus bids. If on the other hand, before the first synthetics plant was constructed a large number of favorable tracts on the Outer Continental Shelf were offered at frequent intervals, and if the drilling proved successful, the development of synthetics could be further delayed. There is already some evidence that the discovery of large petroleum resources in Northern Alaska has changed to some extent the planned timetable for synthetic fuels development by some oil companies.

2. Factors that affect conversion of oil shale to shale oil

a. Title clearance

Approximately 28 percent of the total oil shale acreage is in private ownership, but this contains only a little over 20 percent of the shale oil. Nearly 80 percent of the Federal lands have clouded title, consisting of 36,000 oil shale claims made before 1920 and 16,000 additional claims for various other materials filed since that date.

The pre-1920 claims, i.e., those made before passage of the Mineral Leasing Act, were made under conditions that permitted location and patenting of oil shale deposits. In 1964 several test cases were initiated to establish a set of legal principles for judging the validity of the pre-1920 claims. Hearings on these issues before a hearing examiner of the Bureau of Land Management have been concluded. If a decision adverse to the claimant is issued, an appeal probably will be taken to the Secretary and then to the courts. At best, the issues cannot finally be resolved for several years.

The oil shale lands were withdrawn in 1930 and except for the three test leases recently offered, remain withdrawn. However, the passage of the Multiple Mineral Development Act of 1954 permitted the location of deposits of metalliferous minerals on oil shale lands. There were 5,200 claims filed on the oil shale lands in 1966, apparently in an attempt to obtain title by locating dawsonite on the oil shale lands. In January 1967, therefore, the lands were withdrawn from all mining location.

It is not possible to assess the validity of these more recent claims and nearly 3,000 of the 1966 claims are being contested by the U.S. Department of Interior.

b. The Mineral Leasing Act

Several provisions of the present Mineral Leasing Act, under which oil shale lands are leased, require modification if the lands are to be developed under optimum conditions. The limitation of one lease per person, association, or corporation, is unrealistic if an oil shale industry of any size is to come into existence. Moreover, the provision is a serious obstacle to building the first plant. This is because a pioneering plant might develop the technology at a loss and then be foreclosed from holding a second lease on which it could capture the benefits of that technology. These objections also can be raised with respect to the limitation of 5,120 acres per lease which is another provision of the present law. An acreage limitation has no real meaning since the ratio of the amount of shale oil represented per acre can range from as much as 100 to 1 depending on the thickness and quality of the reserve.

c. Bidding procedures

Under the terms of the Mineral Leasing Act any number of bidding methods is possible. The leasing can be competitive or non-competitive, and the bidding can be oral auction or sealed, profit sharing, bonus bidding, royalty bidding or a combination of these methods. In the test leases offered in December of 1968, competitive sealed bids with a combination bonus and royalty arrangement were used. Other methods might be tried in the future to attract stronger bids. The bidding procedures selected will have a marked effect on oil shale development since potential bidders may prefer one method over another and this could seriously affect the number and size of bids received.

d. Leasing procedures, terms and provisions

While various existing statutes require certain requirements to be stipulated in all leases--such as the non-discrimination clause--there is ample leeway for the lessor to include other provisions which can be designed either to encourage or discourage bidding, or, more important, to force the bidder to discount his bid so heavily that it will be rejected.

Such factors as the number of leases offered per sale, frequency of sales, size of tract offered and the quality of the resource could also be of critical importance to the rate and timing of oil shale development. The initial number of bidders will probably be small, so that the frequency of sales, at least in the beginning, should be low. The tract must contain sufficient shale oil so that a plant large enough to be economic can be supported and paid out with an adequate return in 20 years. At that time, renegotiation is required by the Mineral Leasing Act. In addition, there are great advantages when a resource is just reaching the commercial stage to utilize the highest grade deposits, since if the best deposits are not offered, development would be delayed.

The conditions imposed by the leasing terms can also be critical. For example, a requirement that adequate conservation of the resource be assured can be so strictly interpreted that mining costs would be very high. The time allowed for the payment of royalties and bonuses may be either very short or generous. Conservation standards specified to protect other resource values and to prevent air and water pollution or serious damage to the land could be so strict that costs would skyrocket.

e. Availability of water

While there is sufficient water available in the States of Utah and Wyoming to establish a large oil shale industry without being limited by water availability, the richest known oil shale deposits in Colorado may have some problem with water availability. If the remaining uncommitted water is dedicated to the oil shale industry, and it is used prudently, an oil shale industry capable of at least one million barrels per day could be established (about 7 percent of U.S. consumption). Nevertheless, the only sources of water for the industry are from the Colorado River and its tributaries. These waters serve a very large geographic area and must provide water for both domestic use and a very diverse industrial and agricultural demand.

f. Location of the deposits

The rich oil shale deposits are concentrated in areas of Colorado, Utah, and Wyoming that are largely rural in nature. The establishment of any large new industry would require the development of a highly complex infrastructure that does not now exist and would mean either recruitment or training of various skilled labor and professionals which are not now found in the area. Adequate housing, schools, libraries, transportation and communication systems, water and power services and other community services would have to be provided. If a one million barrel a day oil shale industry were created it would require an additional 115,000 people in an area in which only 72,000 now reside. The orderly development of an infrastructure for such an expanded population would require careful physical and financial planning.

Another adverse effect of the location of the oil shale deposits is on the costs of transportation to refineries and large markets. There is not sufficient water in the area to refine the shale oil on site so it must be pipelined to refineries elsewhere that are located near markets where the finished products can be sold. Pipelining to suitable refineries would add a cost of about 50 cents a barrel to shale oil produced in the Colorado, Utah, and Wyoming area.

g. Environmental protection

Measures to protect the land from the potential adverse effects of mining are largely already fully developed. Air and water pollution as a result of the retorting and semi-refining of the shale oil can be controlled using existing technology. The handling of the spent oil shale, however, could present new environmental problems. With an average shale quality of 30 gallons per ton approximately 1.4 tons of spent oil shale must be handled for each barrel of semi-refined oil shale produced. If the spent shale is returned to the mine from which it was originally taken then this represents an added cost, and may be, on the average, 20 cents per barrel. All of the spent shale could not be replaced in any case since its volume is greater by virtue of the void space present in a mass of broken material as compared to a solid deposit. Thus provision will have to be made for some permanent surface storage of a portion of the spent shale. This will require methods for preventing leaching of the spent shale so that pollution by the leached salts of ground water and streams can be avoided. Where fine shale is used for retorting, provision must be made to stabilize the spent shale to prevent air pollution by blowing fines when the pile is dry.

3. Factors that will affect conversion from coal to oil

Production of liquid fuels from coal will not be affected as much by Federal action or inaction as liquid fuels from oil shale. Unlike the high grade oil shale deposits, coal is found widely dispersed geographically with commercial type deposits reported in 34 states. This is shown in Figure 1. Although as much as 40 percent of these deposits may be on public lands--nearly all of this West of the Mississippi--this still leaves one trillion tons of recoverable reserves in private ownership. In addition, coals of all rank and susceptible to all types of mining systems are owned in abundance by individuals and large coal, oil and steel companies. Therefore, the questions that are crucial in oil shale development, such as title clearance, lease terms and provisions, should not be an important factor in the early stages of development of a commercial coal-to-oil industry.

a. Availability of water

The widespread geographic distribution of the coal deposits means that many of the deposits can be found in areas where the availability of water should create no great problems. All of the coal deposits East of the Mississippi are found in water abundant locations. Many of the large deposits of Wyoming, Montana, and North Dakota are in areas where enough water will be available for an industry. Moreover, competition in these areas for the water would be much smaller and there should be much fewer water rights problems than for the Colorado River and its tributaries. Some coal deposits are, however, found in water deficient areas, and for these locations there would be a choice of moving water to the coal or coal to the water. The selection of which would be done would depend upon other factors such as marketing conditions, the relative costs of transportation of coal, water or the finished oil, and other economic considerations.

b. Location of the deposits

As indicated under the discussion on oil shale, the location of the resource is important because of (1) the need for a well-developed infrastructure to serve the large scale plants that are required to achieve economies of scale, and (2) the importance of transportation costs in bringing the finished products to market. The very large wide-spread geographic distribution of coal, much of it near the centers of great population density and in well established communities where the infrastructure is well developed, and where skilled labor is available, should give coal a competitive advantage over oil shale or tar sands. Moreover, these same population centers would provide markets for the product at much reduced transportation costs.

c. Environmental protection

As in the case of oil shale, methods already exist for preventing adverse effects on the land from mining--either strip or underground. Technology also exists for preventing air or water pollution arising at the coal conversion processing plants. Unlike oil shale, however, solid waste disposal should present no significant problem nor will it involve the costs of disposal that are inherent when oil shale is retorted. Each ton of coal produces about 2.5 barrels of oil and only 200 pounds of ash so that only about 1/25th as much solid waste is generated per barrel of oil produced as when using oil shale. Disposal of the solid waste in the empty space left after the coal was mined would be one solution to the problem. Uses similar to those already developed for fly ash--a material which the waste from conversion plants would resemble--might be found for the solid residue and thus turn a waste material into a useful product, although supply of spent shale could be expected to exceed demand for many years.

d. Other factors

Although conversion of coal appears to have far fewer non-technologic problems associated with its development than oil shale, processes for coal conversion may still not be developed before those for oil shale. At this time, there is considerably more pilot plant experience using various oil shale processes than there is experience with the more advanced coal-conversion processes that will be required for coal-conversion to be competitive with crude petroleum or shale oil. Moreover, coal is much more deficient in hydrogen than the crude shale oil, and the cost of producing the required hydrogen from coal is relatively high. Any breakthrough in hydrogen production costs would cause an important change in the relative attractiveness of coal and oil shale development.

4. Factors that affect tar sands development

Although information on tar sand reserves in the U.S. is limited, it appears that the total reserves of the high quality deposits of sufficient size for a large plant that would be needed for the initial development of an industry are limited. There may be individual deposits which are attractive, but the amount of production from these deposits can be expected to be small. As the need arises for other hydrocarbon sources to meet demand in the next century the lower grade deposits, of which there may be many, could be a useful source of hydrocarbon supply.

The Canadian tar sand reserves of good quality are large and concentrated geographically. The total is estimated at 85 billion barrels recoverable at today's costs. Presently, there is a 45,000 barrel-per-day commercial plant in operation with plans for a larger 80,000 barrel-per-day plant already drawn. Development of Canadian tar sands will be affected greatly by non-technologic factors--Canadian policy with respect to their development in competition with their own crude oil, with oil export policies of the Canadian government and with the joint U.S.-Canadian fuel policy that is now being developed.

5. Other factors common to all synthetics

a. State and local conditions

The actions that state and local governments take with respect to both property and personal taxes, zoning regulations, local conservation and environmental regulations, state water laws, and other related factors could have an important influence on synthetic development. Where deposits are located in remote areas, the actions of state and local government to provide the schools, transportation facilities, roads, libraries, and recreational facilities could have a significant impact on the rate at which an industry develops, since the ability to attract and keep the necessary labor force would be greatly influenced by these factors.

b. Capital requirements

With existing technology, capital requirements are very high, reaching as much as $3,000-$4,000 per daily barrel to produce a synthetic crude oil. This fact, combined with the need for the very large plants required to attain the economies of scale, dictates investments in the range of $300 to $400 million per plant. Few firms would be able to make investments of this size in single plants. Some of the major companies, either alone or in joint ventures, should be able to raise the necessary capital, although even for these very large companies the capital requirements present some obstacle. The high interest rates that are now common also create a detriment to synthetic fuels industries because of the capital-intensive nature of synthetics plants.

c. Institutional practices of the oil industry

There is always a high degree of resistance by an industry to any radical change in raw material sources. There is a reluctance to give up a set of known problems which one has learned to manage, and to attack a completely new set of unknown ones. Coal, oil shale, and tar sands as resources differ from crude petroleum in that the approximate size and quality of the deposits can be ascertained with relative ease. However, they require new methods of processing, and a knowledge of mining technology--a technology generally unknown or unfamiliar to many oil companies. On the other hand, the vertical integration characteristic of much of the oil industry would appear to be useful, and possibly necessary, to a firm entering into a commercial synthetic industry. This suggests that there may be obstacles to the entry into synthetics by other than petroleum companies.

V. Summary

It is obvious that the many public policy issues that are associated with the complex, highly competitive and interrelated fuel resources will have an important impact on the development of a synthetic fuels industry. The demand for liquid fuels is expected to continue to rise in the future, but should a shortage develop, production of synthetics is only one of several ways that this energy requirement could be met. Whether synthetic production would be the preferred method would depend upon its attractiveness compared to that of the alternatives. This, in turn, would depend on both the state of technology, and the effect of non-technologic factors. The major non-technologic factors that are common to the development of any of the synthetics are related to those that affect the price of crude oil with which the synthetics would have to compete. These are (1) the rules governing the imports of crude oil or its products, (2) the depletion allowance, (3) state prorationing practice and (4) Federal leasing policies. Other non-technologic factors that would affect all of the synthetics are (1) state and local regulations, (2) very large capital requirements, and (3) institutional practices of the oil industry.

The non-technologic factors peculiar to oil shale are (1) title clearance problems with the land, (2) provisions of the Mineral Leasing Act, (3) uncertainties with respect to bidding procedures, (4) leasing procedures, terms and conditions, (5) in some areas the availability of water, (6) remote location of the deposits, and (7) extra problems associated with environmental protection.

These seven non-technologic factors are of much less importance for coal than they are for oil shale. The favorable and extensive location of coal deposits and the large private holdings that permit an industry to develop with less government involvement sharply reduce the impact of non-technologic factors. Environmental factors should also be more favorable for coal but, in recent years, larger scale tests of oil shale processes have been made than have been made for coal. The major problem for coal is a technologic one--the high cost of producing hydrogen from coal with which to upgrade the coal to a liquid product.

Known U.S. deposits of tar sands are too small to have any great impact on total liquid fuel supplies. Development of the large reserves of Canadian tar sands, however, could be of no importance in the overall energy supply of North America. Their commercial production will be greatly influenced by non-technologic factors--namely Canadian policies with respect to how they will be developed in competition with Canada's crude oil deposits, Canadian export policies and the terms and conditions of the joint U.S.-Canadian fuel policy which is now under active consideration.

Table 1

Effect of Depletion Allowance on Cost of Synthetic Fuels

		Shale Oil					Coal				
Percentage Depletion (percent)	Point where Depletion is Taken	Cost of Oil Shale \$/ton	Cost of Oil at Retort \$/bbl	Depletion Before Taxes ¢/bbl	Cost of Semi-Refined Oil \$/bbl	Depletion Before Taxes ¢/bbl	Cost of Coal \$/ton	Cost of Crude Synthetic \$/bbl	Depletion Before Taxes ¢/bbl	Cost of Hydro Refined Oil \$/bbl	Depletion Before Taxes ¢/bbl
0	Oil Shale or Coal	1.43	2.68	0	3.93	0	4.40	2.81	0	6.46	0
0	Shale Oil or Synthetic Crude	1.43	2.68	0	3.93	0	4.40	2.81	0	6.46	0
10	Oil Shale or Coal	1.31	2.56	12	3.81	12	4.00	2.66	15	6.31	15
10	Shale Oil or Synthetic Crude	1.43	2.44	24	3.57	36	4.40	2.55	26	5.87	59
15	Oil Shale or Coal	1.25	2.50	18	3.75	18	3.80	2.59	22	6.25	21
15	Shale Oil or Synthetic Crude	1.43	2.33	35	3.93	51	4.40	2.44	37	5.62	84
22	Shale Oil or Synthetic Crude	1.43	2.20	48	3.22	71	4.40	2.30	51	5.30	116
27½	Shale Oil or Synthetic Crude	1.43	2.10	58	3.08	85	4.40	2.20	61	5.07	139

Figure 1
Recoverable reserves of
bituminous coal and lignite
by state 1967